# Technical Evaluation Report

**NORTH ATLANTIC TREATY ORGANISATION**
**RESEARCH AND TECHNOLOGY ORGANISATION**
**SPECIALISTS' MEETING ON**

***Emerging and Future Technologies for Space Based Operations Support to NATO Military Operations***

## SESSIONS

The Specialists' Meeting included three keynote speakers, a poster session and the following four presentation sessions:

- Innovative Architectures
- Data Exploitation
- Space Sensing
- Satellite Technologies

## TOPICS COVERED

Topics discussed at the Specialists' Meeting included:

- Formation Flying
- Distributed Apertures
- Space Based RADAR Systems
- Lightweight Space Structures
- Optical Communication
- Small Satellite Technology
- Data Fusion
- Space Surveillance
- Environmental Remote Sensing

## OFFICIAL REPORT

The first specialist meeting on "Emerging and Future Technologies for Space Based Operations Support to NATO Military Operations" took place in Bucharest, Romania 6−7 September 2006 at the National Military Circle. The meeting was professionally organized by our Romanian hosts. I consider the scientific content to be high and of clear relevance for future NATO operations where space can be a significant contributor in order to gain military superiority. I will not go into details on the different presentations, but rather try to reach some general conclusions. I will also give some advice concerning logistics which I find important for future meetings of this kind.

### Oral and Poster Presentations

All together 25 papers were presented at the seminar as oral speeches. Of these, three were keynote speeches. In addition, eight poster papers were displayed in the conference area. The presentations covered

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a relatively broad range of topics related to space exploitation and exploration. The basic message from most of the speakers was that the battle field will be served/supported by space based systems in a much higher degree than today. Many functions will also be removed from battlespace to secure positions in the homeland, reducing the risk of especially personnel but also vulnerable equipment. The postulated achievements can be categorized in four major sub-groups:

1) New materials
2) Miniaturization
3) Un-denied and fast access to space
4) Changes in operative concepts

The major findings concerning these points can be summarized as follows:

*1) New Materials*

In the years to come, many new materials/technologies will be taken into use. These cover a broad range from light-weight (adaptive) membranes, carbon nano-tubes, MEMS, nano- and biotechnology, high-energy density material to mention a few. These materials and technologies will revolutionize military operations in the future. Of special interest is that the use of these materials will result in systems that can be operated from the homeland and not in the battlefield. This will have a clear psychological effect, both concerning own forces that do not need to expose themselves to danger and to opposing forces that do not "see" their enemy. Although this is a situation that will not be achieved for several years, some elements of it will possibly be in place in a 5−10 years timeframe. Carbon nano-tubes will be used for a number of purposes. Of special interest is the design of tethers with extreme strength. These can withstand the electromagnetic forces and instead utilize these forces as a mean of propulsion. Relatively cheap access to geostationary orbit may be the result in a 20−30 years timeframe. In the long term, new types of energy propulsion such as zero-point energy and even anti-matter will be used. These types of energies can provide more than $10^{10}$−$10^{12}$ times today's chemical energy and will really revolutionize space transportation (not only satellites, but manned missions to e.g. Mars too).

*2) Miniaturization*

One of the main challenges to gain access to space today is the large costs involved in reaching orbit. The use of new materials will lead to the development of both smaller and light-weight satellites. This will make it possible to launch clusters of small satellites and/or satellites that contain elements that can unfold much larger structures in space than today. The proposed use of new types of light-weight membranes is in this respect very interesting. Large 100−1000 meter antennas can be unfolded to give them their final shape when the satellites reach orbit. So-called rainbow solar arrays will also be taken into use in order to exploit larger parts of the spectrum, giving them a much higher degree of efficiency (70 %). These large membranes can be used for both communication as well as e.g. so-called target illuminators. A cluster of very small satellites (pico-satellites) will also serve some of the same purposes as the membranes. Some of the applications are communication and synthetic aperture radars (SAR).

*3) Un-Denied and Fast Access to Space*

The introduction of very small satellites will significantly reduce the time between project initiation and launch. Many satellites will also be "mass-produced" and can be taken off-the-shelf and launched within a week in specific situation. Several countries have already such projects under consideration, with some test-launches scheduled for the near future (e.g. Canada, UK and USA). One possible use of such satellites is to place them in orbits to observe a specified battlefield and transmit more or less real time pictures to blue forces during actual battle situations. This may be a significant contributor to reduce loss of life during an operation. A possible problem is that this development of small (and low-cost) satellites will lead to space becoming egalitarian. Other countries will also have access to such satellites and even

guerrillas can conceivably be potential users, such that this trend may result in additional threats against own forces. This should not be underestimated.

*4) Changes in Operative Concepts*

Both the development of new materials and the miniaturization of future satellites will lead to significant changes to operational concepts. The most significant of these is perhaps that many functions in actual battle situations can be performed from homeland. These functions cover a broad area of applications ranging from passive (e.g. surveillance) to active behaviour (remote launch of weapons). Space will therefore be more and more militarized in the years to come. This will also enhance the possibility for "space battle", because significant and important systems in space may become targets in future conflicts. Redundancy is therefore an important aspect of future space systems. Systems that are in use today should not be completely abolished, but some of them should be maintained as backup systems at least for some years. The trend is however relatively clear: an increasing number of functions will be performed from space in the future.

**Other Aspects**

Other aspects not directly linked to the points above, or mentioned there, were also presented at the workshop. These can shortly be summarized in the following phrases:

- Self-assembling structures will be developed
- Space jamming systems (to jam systems on the ground) will be put in orbit
- Detection of chemical releases from space
- Ballistic missile defence; also active layer theatre BMD
- Multi-static radars to detect ground-moving targets will be put in orbit
- Space based antenna to detect small objects in terrain will be developed
- Satellites providing high capacity and secure communication links in theatres will be developed
- Tactical imaging satellites supporting war fighters in the theatre will be put in orbit
- ESA will in the future also be involved in NATO exercises

What is written in this section shows that there is a raving development of new and innovative space systems. The completion date for these systems range from a few years ahead to many decades. The main impression from the presentations given at the workshop is that there is an ever increasing interest to exploit space for military purposes.

## Technical Comments

The meeting was arranged at the National Military Circle in Bucharest, Romania. The logistics were professionally handled by the organizing committee and the local hosts. I have, however, a few comments and suggestions for improvements that organizers of future meetings should consider:

- The meeting room was very picturesque and magnificent. The participants were placed around a rectangular table with microphones available to ask questions after each presentation. However, the screens on which the presentations were displayed were generally too small for many of the participants to grasp all the details on the slides. I will therefore give the advice that either larger screens or a layout of the meeting room as a small auditorium should be used in the future.
- Related to item 1 is the fact that many of the presentations contained too much information on each slide. As a consequence, the fonts applied were also too small. A number of the participants

could therefore not see what was displayed on the screen. A pre-screening of the presentations by the organizing committee in the future should therefore be considered to avoid such problems.

- The papers as well as all presentations were made available to me as technical evaluator during the meeting. I greatly appreciate that this was possible. For future meetings I strongly recommend to do the same. If possible, some, if not all, of the presentations could have been made available even before the meeting. This requires that there must be an absolute deadline for the authors to submit their papers in advance, which may not be achievable in all cases. Future committees should consider this possibility.

## Scientific Paper Selection

The organizing committee has put together a programme with invited keynote presentations and contributed talks as well as some poster papers. The meeting was coloured by this choice and functioned more as a conference, and not so much as a workshop as it was meant to be. I thus have the feeling that the discussion that took place after each presentation was generally too short. I recommend that for future meetings, where a list of topics as for the present meeting has been chosen in advance, the focus should be on invited and keynote talks. I think this will give the participants the opportunity to go much more into detail on each topic, thus enhancing the scientific outcome of the meeting. These presentations should e.g. be given one hour each for presentations and immediate questions. A summary/discussion session at the end of each day (or at the end of each presentation session) could also be scheduled to discuss the material in broader context. This will, for me at least, give the meeting more the flavour of a workshop.

## Summary

The presentations cover a broad spectrum of topics related to space exploration (mainly the poster papers) and space exploitation. I will not go into details concerning the individual presentations, but rather give a broad and preliminary overview.

We have heard the authors speaking of everything from details of specific systems and projects to more visionary views on what the future might bring. I find this mixture fascinating. Without visions, it is not very likely that new and disruptive systems will ever see daylight. On the other hand, we need people that can turn the visions into real systems that can be used for military purposes.

Space is becoming more and more important for future military operations. One of the reasons is related to the fact that we tend to no longer accept loss of personnel. However, we should also be aware that placing military systems in space we also expose them to damage, both natural and man-made (attack). We should therefore not totally replace Earth-based systems with space-based ones. Some sorts of back-up systems are needed, at least for some tasks as e.g. communication and navigation.

If I should make one critical remark at the end, I could have wished the speakers to focus more on the aspect of how NATO forces could benefit from the new technologies and development and perhaps less emphasis on the system itself. I know this is a difficult question to cope with, but I anyhow put it on the table for future consideration.

For me, the specialists' meeting was very successful. If I should summarize my impression in a short statement, it can be phrased like this:

> **Future space systems, not only military, will be small (perhaps ultra-small), inexpensive, to a large degree autonomous, with similar performance as today's large systems, and with the use of new innovative materials a cluster of smaller satellites will outrank the systems of use in space today.**